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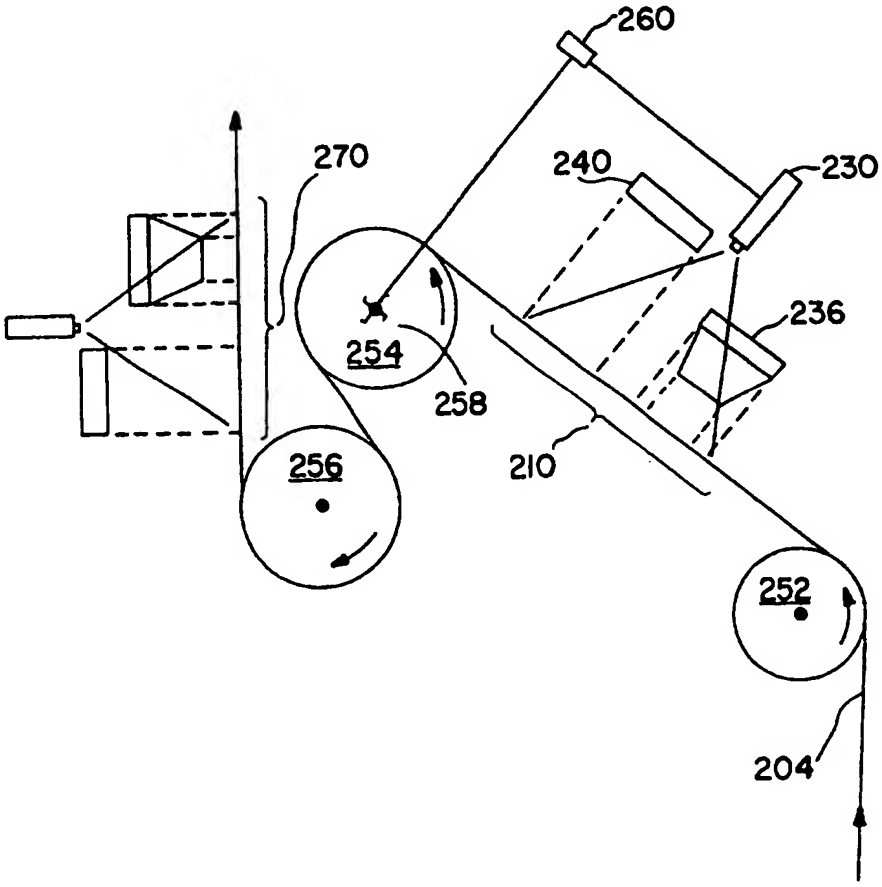
(54) Title: METHOD AND APPARATUS FOR IMAGING SURFACES

(57) Abstract

A method and apparatus for imaging the surface of an object is provided. The object (204) is moved through an inspection region (210) where it is illuminated using at least two types of illumination (236 and 240). An integrated image is obtained which advantageously includes different types of surface characteristics that, individually, are visible only under one of the two types of illumination. In a preferred embodiment, the object being monitored is a continuous web of material such as a metal sheet.



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METHOD AND APPARATUS FOR IMAGING SURFACES

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a method and apparatus for imaging the surface characteristics of an object. In particular, the present invention is directed to a method and apparatus for imaging the surface of an object as the object moves through an inspection region.

2. Description of Related Art

Video cameras have been used as a means of inspection for various applications including the inspection of electronic circuit boards and the inspection of moving webs of material such as plastic, paper and metals. In these applications the video camera images the object and the image obtained by the camera is evaluated for the presence of contaminants, the orientation of the object, the identification of the object or the measurement of geometric dimensions on the object.

For some applications, a charge coupled device (CCD) camera has been utilized. In conventional CCD cameras, light reflected from the object being observed is focused onto an image section of a CCD sensor that comprises an array of photoelements, for a selected interval of time. The time interval is selected to produce acceptable image contrast without significant blurring of the image due to the motion of the object. The stored charge representing the light intensity reaching the photoelement is

periodically shifted from the image section to a storage section and each element is thereafter erased or reset.

CCD cameras have also been modified to operate in time delayed integration (TDI) mode. In this mode, the charge representing the light intensity reaching the photoelement is shifted to the next row simultaneously with the light pattern impinging upon the photoelements from the moving object. Thus, the charge representing the light reflected from a selected portion of the object is integrated as the object moves. When the last row of photoelements is reached, the accumulated charge is shifted into a storage section.

U.S. Patent No. 4,922,337 by Hunt et al. discloses a method of quality control utilizing a CCD camera operating in TDI mode and teaches the operation of a CCD camera in TDI mode. U.S. Patent No. 5,085,517 by Chadwick et al., discloses a method for high speed optical inspection of printed wire boards using a CCD camera in TDI mode.

Known inspection systems utilizing video camera means have been found to fail in detecting different types of surface features on an object, such as a moving web of metal.

It would be advantageous to provide a method and apparatus for inspecting objects wherein different types of surface features can be imaged and detected.

SUMMARY OF THE INVENTION

The present invention is directed to a method and apparatus for imaging the surface of an object, such as a continuous web of material.

It has been found that when inspecting certain types of objects, particularly continuous webs of metal, certain surface features are not readily visible under typical lighting conditions. For example, it has been found that certain surface defects that can occur in a metal sheet are more readily visible under bright field illumination while other surface defects are more readily visible under dark field illumination. Therefore, it would be advantageous to provide an apparatus and method capable of imaging different surface features simultaneously. It would be particularly advantageous if such an apparatus and method was capable of imaging the object as the object moved continuously through an inspection region.

According to one embodiment of the present invention, an apparatus for inspecting the surface of an object is provided. The apparatus can include illumination means for illuminating the object as the object moves through an inspection region wherein a portion of the illumination means illuminates the object with dark field illumination and a portion of the illumination means illuminates the object with bright field illumination. The apparatus also preferably includes imaging means for imaging the object within the inspection region to produce a composite image

of the object under both dark field illumination and bright field illumination.

The apparatus preferably includes a single CCD camera operating in TDI mode to image the object in the inspection region. The illumination means can include separate illumination sources for providing bright field and dark field illumination. In one embodiment, substantially separate portions of the inspection region are illuminated by the bright field and dark field illumination. The apparatus can also include conveying means for moving objects through the inspection region.

According to another embodiment of the present invention, a method for imaging the surface of an object includes the steps of illuminating a first portion of an inspection region with dark field illumination and illuminating a second portion of the inspection region with bright field illumination. An object is then placed in the inspection region and is imaged to produce a composite image of bright field and dark field illumination. The object can be imaged with a CCD camera, preferably operating in TDI mode. The use of a CCD camera operating in TDI mode allows an image of the object to be generated that can include different surface features in a single image. Preferably, the image is inspected to determine if any defects are present on the object.

In a preferred embodiment, the object is conveyed through the inspection region in a substantially continuous fashion and the object can be larger than the illuminated

portions. In a another preferred embodiment, the object is a continuous web of material such as a continuous sheet of metal. The illumination can include at least two illumination sources having different primary wavelengths.

The method and apparatus of the present invention are particularly useful as an integral part of a process for producing cast aluminum sheet, and one embodiment of the present invention is directed to a method for the production of aluminum alloy sheet stock that includes the steps of casting an aluminum alloy metal to form a cast sheet, hot rolling the cast sheet to form a hot rolled sheet, cold rolling the hot rolled sheet to form a cold rolled sheet, and inspecting the cold rolled sheet by illuminating a first portion of an inspection region with dark field illumination and illuminating a second portion of the inspection region with bright field illumination, moving the cold rolled sheet through the inspection region and imaging the cold rolled sheet to generate an image of at least a portion of the cold rolled sheet wherein the image is a composite image of the portion under bright field illumination and dark field illumination

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 illustrates examples of bright field and dark field illumination according to the present invention.

Fig. 2 illustrates an apparatus according to the present invention for inspecting a moving web.

Figs. 3a and 3b illustrate two views of an illumination system for inspecting objects according to one embodiment of the present invention.

Fig. 4 illustrates illumination means for inspecting objects according to one embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is directed to a method and apparatus for inspecting the surface of an object as the object moves through an inspection region by illuminating the object with bright field and dark field illumination. The method and apparatus are particularly applicable to the inspection of continuous webs of material for defects or irregularities on the surface of the material. Processes in which continuous webs of material are routinely inspected include the fabrication of sheets, films and rolls of plastics, metals, glass, plywood, paper, fabrics and the like. The method and apparatus are particularly applicable to the inspection of continuous webs of reflective metal, such as aluminum, copper, bronze and the like. For example, the method and apparatus can be particularly useful as an integral part of a process for producing aluminum alloy sheet stock. An example of such a process is disclosed in U.S. Patent No. 4,976,790 by McAuliffe et al.

The terms bright field illumination and dark field illumination refer to the way that the object is

illuminated by one or more illumination sources. Whether the object is illuminated in bright field or dark field depends on the angle of incidence of the illumination relative to the object being viewed and the position of the observer or imaging camera relative to the object being viewed. Therefore, whether the illumination is dark field or bright field can be determined by the position of the illumination source and/or the position of the imaging camera.

Bright field illumination refers generally to a setup wherein illumination is directed at the surface of the object such that the light that is reflected from the object to the imaging camera is reflected in a specular mode. That is, the light is reflected to the camera at an angle approximately equal to the incident angle of the illumination relative to a normal to the object's plane. For example, the illumination source can be positioned such that the light strikes the surface of the object substantially normal to the object's plane (e.g., about 90° to the plane) wherein the imaging camera is positioned directly over the object. Alternatively, the illumination can be directed at the surface of the object at an angle that is close to 90° to the object plane (e.g., from about 70° to about 90° to the plane) and the camera can be positioned at a substantially similar angle on the opposite side of the object.

The term "dark field illumination", as used herein, refers generally to a setup wherein illumination that is

detected by the camera is predominantly light that is diffused by the surface of the object. Dark field illumination can be provided, for example, by an illumination source that directs light at the surface of the object at a glancing angle, for example less than about 45° to the plane of the object. The imaging camera is positioned to reduce the amount of specular reflection that is detected from the illumination source.

Bright field and dark field illumination can be understood in more detail by reference to Fig. 1 which illustrates the manner in which illumination can be reflected from the surface of an object. A substantially planar object 104 is illustrated in Fig. 1. Light beam 112 is directed at the object 104 in a direction that is close to the normal 118 to the plane of the object 104. The light beam 112 strikes the object 104 and is predominately reflected upwards in a specular mode where the specular reflection 114 is detected by a camera 130. This is the bright field illumination. The diffuse reflections 116 that reflect from the surface of the object 104 are predominately reflected outside of the field of view of the camera 130.

Dark field illumination can be achieved by directing a light beam 120 at the object 104 at a small angle in relation to the plane of the object 104. When the light beam 120 strikes the surface of the object 104, a portion 122 of the reflected illumination is reflected upward towards the camera 130 in diffuse mode thereby creating

dark field illumination. The specular reflection 124 is reflected out of the field of view of the camera 130. Illumination striking the surface of the object at a small angle can be diffusely reflected to the camera by microscopic or macroscopic surface roughness, by surface features or by the presence of foreign material on the object. Fig. 1 is for illustration by example only, and it is to be understood that many types of surface conditions can exist that can reflect incident light in different ways.

As is discussed hereinabove, the method and apparatus of the present invention are particularly applicable to the inspection of continuous webs of material. It has been found that among the many types of defects possible in a continuous web of some materials, certain defects will not be easily detectable under bright field illumination while other defects will not be easily detectable under dark field illumination. For example, the method and apparatus of the present invention are particularly applicable to the inspection of continuous sheets of reflective metal, such as aluminum sheet metal used to fabricate drawn and ironed beverage containers. During the fabrication of aluminum metal sheet, many types of defects can occur. Discoloring effects such as oxide bands, grease spots, water stains and the like are most easily detected by illuminating the sheet with bright field illumination. However, other defects such as scratches, laminations, and dents in the sheet cannot readily be detected under bright field illumination and

these types of defects are more easily detected using dark field illumination. Therefore, in order to adequately image different types of defects, it is desirable to use both bright field illumination and dark field illumination.

However, it has not heretofore been possible to illuminate an object with both bright field illumination and dark field illumination to produce a composite image since bright field illumination will tend to flood out any reflections from the object resulting from the scattering of dark field illumination. The present invention addresses this problem.

Referring to Fig. 2, an apparatus for inspecting a moving web of material according to one embodiment of the present invention is illustrated. In this embodiment, a continuous web of material 204, for example aluminum sheet, is conveyed through an inspection region 210. In one embodiment of the present invention, the inspection region can be an integral part of a process for producing aluminum sheet stock. In such a process, aluminum metal is cast and then treated in a series of hot rolling and cold rolling steps to reduce the thickness of the aluminum sheet. Intermediate annealing steps between rolling steps can advantageously enhance the properties of the metal sheet. The inspection region 210 can be placed anywhere in the process where it is advantageous to inspect the web and in a preferred embodiment the web is inspected after the final rolling step.

Additional inspection regions can be used as necessary. For example, when inspecting a continuous web, a second inspection region 270 can be used so that both sides of the web are imaged. In the case of a continuous web of material such as a continuous sheet of metal, the conveying means can include a series of rollers 252, 254, and 256 that rotate to convey and maintain tension in the sheet. The rollers 252, 254, and 256 can conveniently be an integral part of a fabrication or finishing process, such as a process for applying a protective film to the sheet or a process for leveling the sheet.

When discrete objects are being inspected, the conveying means can include, for example, a conveyer belt for supporting and moving the objects through the inspection region.

As the continuous web 204 is conveyed through the process it enters an inspection region 210. The inspection region is defined by the field of view of the camera 230. The speed of the continuous web 204 moving through the inspection region 210 can be controlled by adjusting the speed of the rollers 252, 254 and 256 to rotate the rollers 252, 254 and 256 at a substantially constant frequency. Tachometer means 258 can also be used to monitor the rotational speed of the rollers and hence the speed of the continuous web 204 moving through the inspection region 210. For example, the tachometer means 258 can be electronically connected to control means 260 for regulating the speed of the rollers. The tachometer means

258 can also be electronically connected to the camera 230 to slave the speed of the object movement with the charge transfer rate in the camera. The tachometer means 258 can also be connected to the illumination sources 236 and 240, as is described in more detail hereinbelow. Preferably, the conveying means maintains the object at a substantially constant speed.

According to the present invention, the inspection region 210 is illuminated with both dark field illumination from a dark field illumination source 236 and bright field illumination from a bright field illumination source 240 to produce a dark field image and a bright field image. As the object passes through the inspection region, it is illuminated with both types of illumination. Preferably, the bright field illumination and dark field illumination do not substantially interfere (e.g., overlap) with one another. In one embodiment of the present invention, the inspection region 210 includes two distinct portions wherein one of the portions is subjected to bright field illumination while the other portion is subjected to dark field illumination. Some overlap of the bright field and dark field illumination is acceptable, however, it is believed that for most applications better results will be realized when the amount of overlap is minimized.

In one embodiment of the present invention, the illumination can be provided by two or more separate illumination means that provide the desired illumination effects. Referring now to Figs. 3a and 3b, an apparatus

according to one embodiment of the present invention is illustrated. In Fig. 3a, the web is moving from left to right and in Fig. 3b the web is moving out of the page. The apparatus includes a camera 330, preferably a CCD camera operating in TDI mode. An illumination source 340 provides bright field illumination to the moving web 304. In Fig. 3b, dark field illumination source 332 is illustrated. Optionally, an additional dark field illumination source 336 can also be provided. The angle at which the dark field illumination source is positioned with relation to the object can be changed to suit the type of object being inspected. As Fig. 3a illustrates, the field of illumination for the dark field illumination source 332 and bright field illumination source 340 do not substantially overlap.

The illumination source can be any light source that is convenient for providing illumination to the moving web. In a preferred embodiment, the illumination sources 332, 336, and 340 utilize standard 48 inch fluorescent bulbs. For example, each illumination source can include two 48 inch fluorescent bulbs placed substantially parallel to one another in a rectangular box approximately 12 inches wide by 50 inches long. Fluorescent lights are generally preferred since they generate less infrared (heat) energy than, for example, incandescent lights. Preferably, the box includes a diffuser for diffusing the light as the light passes through the box and towards the object. The diffuser can be made from, for example, a translucent

plastic sheet. Such a sheet will advantageously minimize the appearance of horizontal bright bands on the surface of the object as the object moves through the inspection region.

It is also believed that illumination sources of different primary wavelength can illuminate different types of surface characteristics better than standard types of illumination sources that emit a broad spectrum of wavelengths. For example, grease spots on a highly reflective metal sheet can be more easily detected under ultraviolet light than under standard fluorescent light. Also, defects in polymer films that are often applied to aluminum metal sheets may be more readily detected under infrared lighting. Therefore, according to another embodiment of the present invention, the illumination means includes at least two different types of illumination sources capable of providing light of different primary wavelengths. For example, an ultraviolet illumination source or an infrared illumination source can advantageously be used.

The illumination sources are preferably regulated to account for sudden power fluctuations that may occur during operation. The intensity of the light will therefore remain substantially constant throughout the process. Further, since fluorescent light sources can degrade by as much as 15% during the first 100 hours of use, the light sources are preferably regulated to automatically correct the current and maintain a substantially constant level of

light intensity. The light source can also be slaved to the tachometer means so that the intensity can be reduced when the object movement slows down, thus increasing the time that the image is exposed to the illumination.

Other means can also be utilized to provide portions of dark field illumination and bright field illumination to the inspection region, such as a single light source. For example, Fig. 4 illustrates a fiber optic light pipe that can be utilized to provide a continuum of both dark field and bright field illumination to the object. In this embodiment, the center 410 of the light pipe 400 is raised above the surface of the object 420 at one end of the inspection region to provide bright field illumination. The light pipe 400 is then tapered down and to the sides of the inspection region such that the light pipe 400 is closer to and at the sides of the object 420 near the opposite end of the inspection region to provide dark field illumination.

Referring to Fig. 3, the illumination from both the dark field and bright field illumination sources is preferably imaged with a CCD camera 330 operating in TDI mode. A camera that is particularly useful in the present invention is the Visioneer 4050 camera available from Sierra Scientific of Sunnyvale, CA.

The preferred CCD camera 330 includes a two-dimensional array of light sensitive photoelements. When illumination striking the object is reflected to the camera, photons enter the photoelements and electrons are

released. The electrons migrate to a potential energy well created by clock lines on the face of the array. Once a row of charge has accumulated on the photoelements, it can be moved to an adjacent row of photoelements by changing the voltages on the clock lines.

In the TDI mode, the charge is transferred in a row from photoelement to photoelement. At each photoelement additional charge corresponding to the photons reaching the photoelement is added to the transferred charge. The photoelements are controlled in such a way that the accumulated charge is transferred in synchronization with the movement of the object being imaged. Thus, as the object moves some small increment, the charge is shifted one row to follow the motion. If there are 244 rows of photoelements, then the total exposure time for each small area of the image will be 244 times as long as a single row imager or line scan camera. The size of the CCD array can vary, and in one embodiment the CCD camera 330 comprises a 244 X 610 array of photoelements.

The rate at which accumulated charge is transferred between rows preferably corresponds to the rate at which the object passes through the inspection region 210 (Fig. 2). For example, when inspecting continuous webs of metal, the metal web may move at rates of from about 1000 to about 4000 feet per minute. The synchronization can be accomplished using a conveyor speed sensor or tachometer means 258 connected to the camera to clock the CCD array at a corresponding rate. Further, the tachometer means 258

can be connected to the power source for the illumination means 236 and 240 to dim the illumination means 236 and 240 when the speed of the conveying means decreases.

Thus, the charge is shifted from row to row along the CCD array in synchronization with the movement of the object being imaged. If the lens of the camera focuses a 1 millimeter x 1 millimeter area of the object on each photoelement of the CCD array, then each time the object moves 1 millimeter, the integrated light values are shifted one row or line in the CCD array. Eventually, the charge representing the integrated light values reaches an optically insensitive storage section where the total accumulated charge is stored temporarily.

This process allows an image to be formed that represents a row of the object as integrated over the entire inspection region. Thus, for any point on the object being imaged, the total charge accumulated represents illumination reflected or diffused from the surface of the object at that point in both bright field and dark field illumination. Different types of defects will therefore be visible in the same image.

The charge that is accumulated eventually reaches a storage section where the integrated value of the row is stored for image processing. The image can then be processed through a computer hardware system that converts the data to digital images.

In a preferred embodiment of the present invention, the image that the camera captures is converted to a

digital image in a frame grabber. The frame grabber gathers images of the object in lines, which are assembled in the frame grabber into whole frames that can be viewed and processed by computer software programs. Each frame represents the object being imaged or a portion of the object being imaged, such as a portion of a continuous web. The software can scan the image for defects by comparing the image to a standard image that does not contain defects and looking for changes in pixel values. Images that the system identifies as containing defects can then be saved onto a storage device such as a hard disk drive. An operator can scan the defect images on the hard drive to either save or discard the defect image and to classify the defect if it is saved. For example, a trained operator may be able to distinguish between a water stain on a metal sheet and a grease mark on the sheet. The operator can classify the defect accordingly and may be able to decide if the flaw is critical or can be ignored. Information about the defect, for example, its size, location, severity, and classification, can be saved as a part of a data file on the objects being inspected.

The present invention thus provides a method and apparatus for imaging the surface of objects such that features visible under bright field illumination and features visible under dark field illumination are both visible in one composite image.

While various embodiments of the present invention have been described in detail, it is apparent that

modifications and adaptations of those embodiments will occur to those skilled in the art. However, it is to be expressly understood that such modifications and adaptations are within the spirit and scope of the present invention.

What is claimed is:

1. A method for imaging the surface of an object, comprising the steps of:

(a) illuminating a first portion of an inspection region with dark field illumination and illuminating a second portion of said inspection region with bright field illumination;

(b) placing said object in said inspection region; and

(c) imaging said object to generate an image wherein said image is a composite image of said object under bright field illumination and dark field illumination.

2. A method as recited in Claim 1, wherein said object is a continuous web.

3. A method as recited in Claim 2, wherein said web comprises a continuous metal sheet.

4. A method as recited in Claim 3, wherein said metal sheet comprises aluminum.

5. A method as recited in Claim 1, wherein said imaging step comprises the step of imaging said object with a CCD camera operating in TDI mode.

6. A method as recited in Claim 5, further comprising the step of determining if a defect is present on said object.

7. A method as recited in Claim 6, wherein said defects include defects visible under dark field illumination and defects visible under bright field illumination.

8. A method as recited in Claim 1, wherein said placing step comprises the step of moving said object through said inspection region substantially continuously.

9. A method as recited in Claim 1, wherein said illuminating step includes the step of illuminating said object with a illumination having a primary wavelength different than either of said dark field or said bright field illumination.

10. A method as recited in Claim 1, wherein said object has an area greater than the area of said first portion and said second portion.

11. A method as recited in Claim 1, wherein said first portion and said second portion do not substantially overlap.

12. A method as recited in Claim 1, wherein said bright field illumination and said dark field illumination are provided by a single light source.

13. A method as recited in Claim 12, wherein said single light source comprises a fiber optic light pipe.

14. A method for inspecting the surface of a continuous web of material, comprising the steps of:

(a) illuminating a first portion of an inspection region with dark field illumination and illuminating a second portion of said inspection region with bright field illumination;

(b) moving said continuous web of material substantially continuously through said inspection region;

(c) imaging said web with a CCD camera operating in TDI mode to form composite image of said web; and

(d) inspecting said composite image to determine whether said web comprises defects.

15. A method as recited in Claim 14, wherein said continuous web of material is a continuous metal sheet.

16. A method as recited in Claim 15, wherein said metal is selected from the group of aluminum, copper, and alloys thereof.

17. A method as recited in Claim 14, wherein said inspecting step comprises the step of using programmed computer means to identify a possible defect.

18. A method as recited in Claim 17, wherein said composite image is manually inspected to classify the defect.

19. An apparatus for inspecting the surface of an object, comprising:

(a) illumination means for illuminating the object as the object moves through an inspection region wherein a first portion of said illumination means illuminates the object with dark field illumination and a second portion of said illumination means illuminates the object with bright field illumination; and

(b) imaging means for imaging the object within said inspection region to produce a composite image of said object under dark field illumination and bright field illumination.

20. An apparatus as recited in Claim 19, wherein said imaging means comprises integrating means for integrating images obtained under dark field illumination and images obtained under bright field illumination.

21. An apparatus as recited in Claim 19, wherein said imaging means comprises a CCD camera operating in TDI mode.

22. An apparatus as recited in Claim 19, wherein said illumination means comprises at least two illumination sources.

23. An apparatus as recited in Claim 22, wherein one of said two illumination sources provides dark field illumination and one of said illumination sources provides bright field illumination.

24. An apparatus as recited in Claim 23, wherein said bright field illumination and said dark field illumination illuminate substantially separate portions of the inspection region.

25. An apparatus as recited in Claim 19, further comprising conveying means for conveying the object through an inspection region.

26. An apparatus as recited in Claim 25, wherein said conveying means comprises a plurality of rollers.

27. An apparatus as recited in Claim 25, wherein said conveying means comprises a conveyer belt having a plurality of objects disposed thereon.

28. An apparatus for inspecting the surface of a continuous web of material, comprising:

(a) conveying means for conveying said web through an inspection region;

(b) illumination means for illuminating said inspection region wherein said illumination means illuminates a first portion of said inspection region with dark field illumination and illuminates a second portion of said inspection region with bright field illumination; and

(c) camera means for imaging said web as said web passes through said inspection region wherein said camera means integrates said image to produce a composite image of dark field illumination and bright field illumination.

29. An apparatus as recited in Claim 28, wherein said camera means comprises a CCD camera operating in TDI mode.

30. An apparatus as recited in Claim 28, further comprising tachometer means operatively connected to said conveying means to monitor the speed of said conveyor means.

31. An apparatus as recited in Claim 30, wherein said tachometer means is operatively connected to said camera means to synchronize the speed of said conveying means with said CCD camera.

32. An apparatus as recited in Claim 28, wherein said illumination means comprises at least two independent illumination sources.

33. An apparatus as recited in Claim 32, wherein said first portion and said second portion do not substantially overlap.

34. An apparatus as recited in Claim 28, further comprising programmed computer means for inspecting said composite image to determine if a defect exists on said web.

35. An apparatus as recited in Claim 28, wherein said web is a continuous metal sheet.

36. A method for the production of aluminum alloy sheet stock, comprising the steps of:

(a) casting an aluminum alloy metal to form a cast sheet;

(b) hot rolling said cast sheet to form a hot rolled sheet;

(c) cold rolling said hot rolled sheet to form a cold rolled sheet; and

(d) inspecting said cold rolled sheet, said inspecting comprising the steps of:

(i) illuminating a first portion of an inspection region with dark field illumination and illuminating a second portion of said inspection region with bright field illumination;

(ii) moving said cold rolled sheet through said inspection region; and

(iii) imaging said cold rolled sheet to generate an image of at least a portion of said cold rolled sheet wherein said image is a composite image of said portion under bright field illumination and dark field illumination.

37. A process as recited in Claim 36, further comprising the step of applying a polymer film to said cold rolled sheet prior to said inspecting step.

FIG. 1

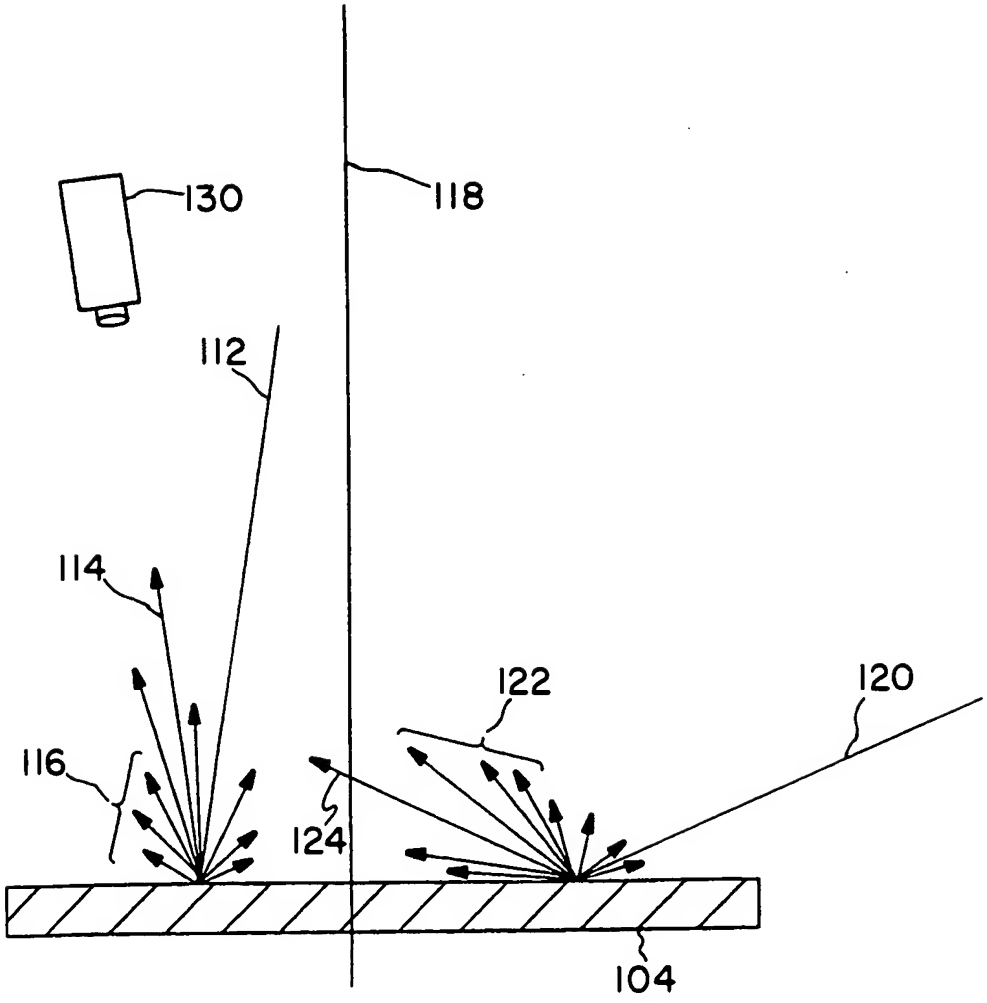


FIG.2

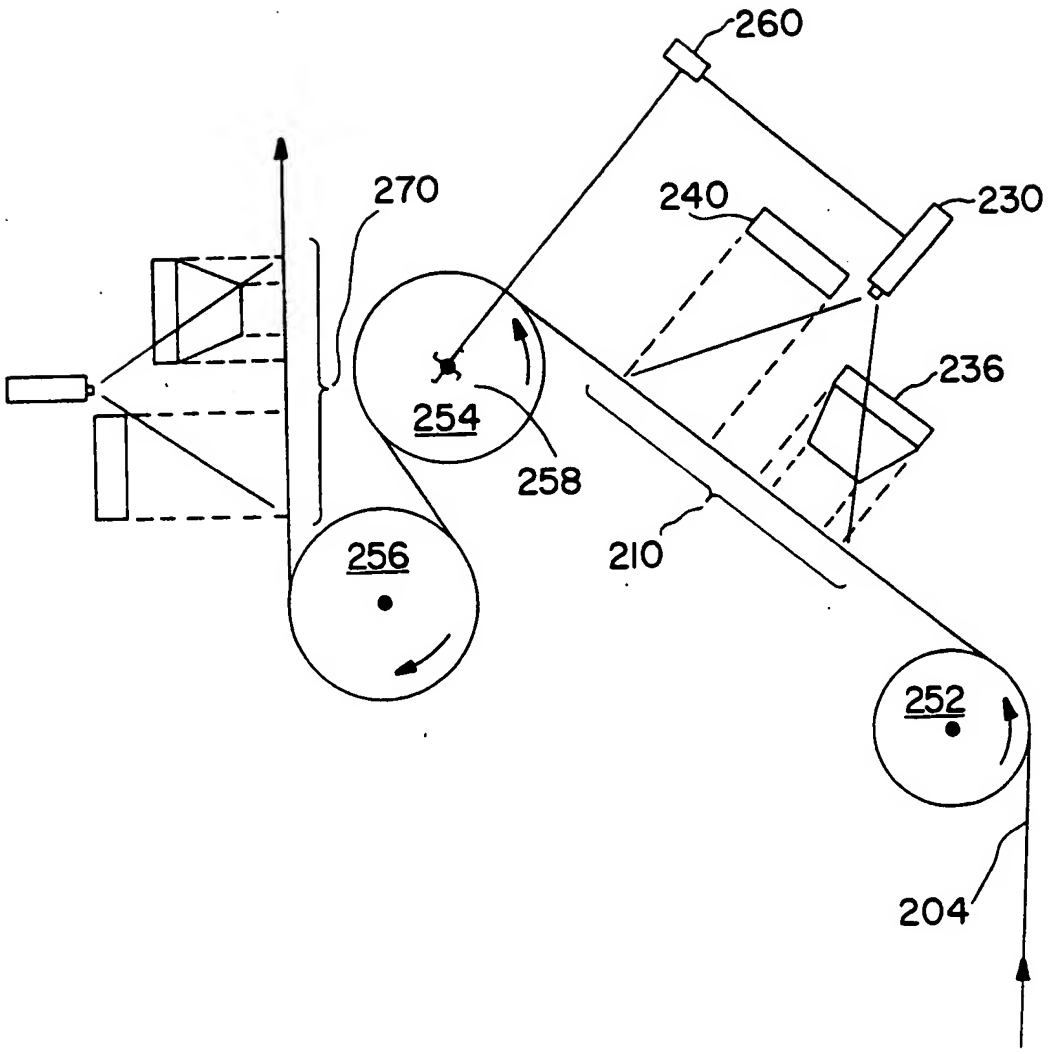


FIG.3A

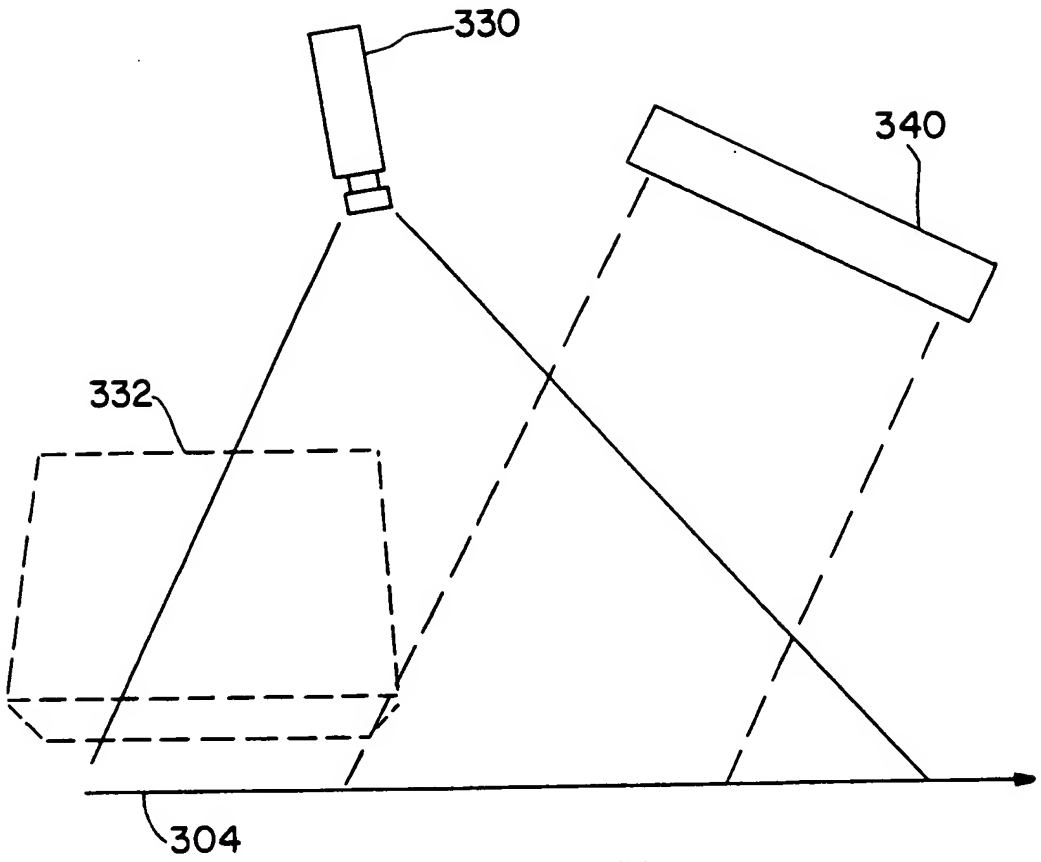


FIG.3B

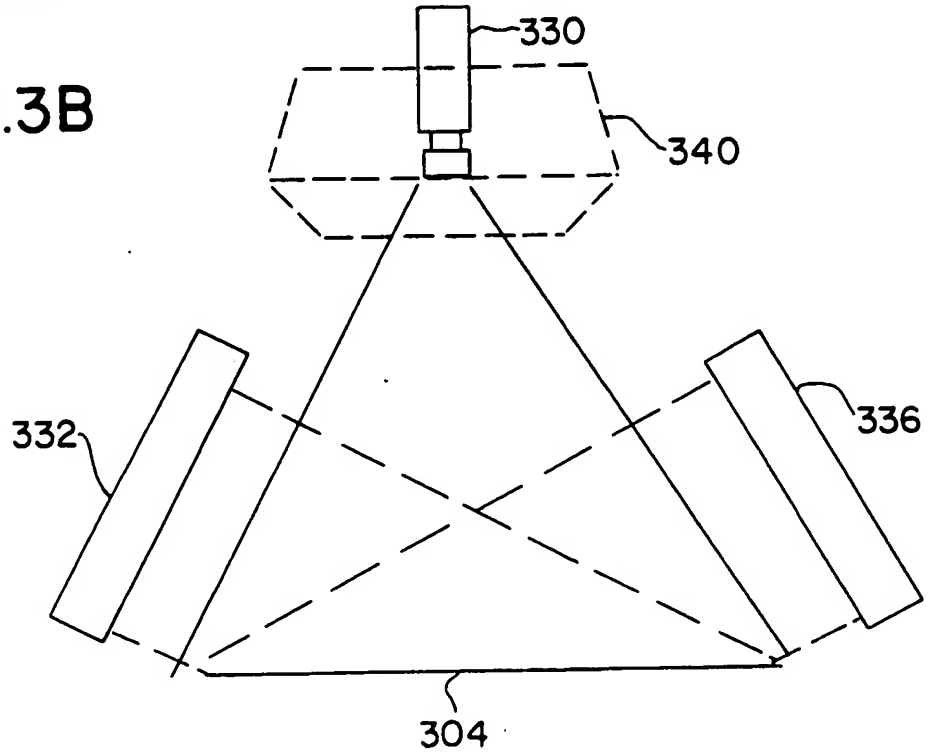
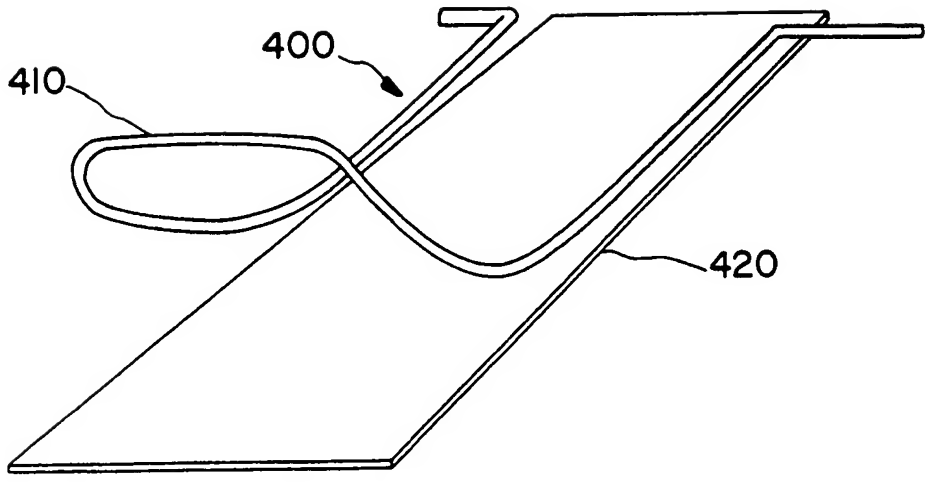


FIG.4



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US93/12141

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :G06K 9/00
US CL :382/8
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : Please See Extra Sheet.

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US, A, 5,030,008 (Scott et al.) 09 July 1991, figures 1, 3 and 7a and column 5, lines 3-8 and column 6, line 5 through column 7, line 25	1-2, 4-14, 17-20, 22-25, 28 and 32-34 --- 3-5, 15-16, 21, 26-27, 29-31 and 35
Y	US, A 4,922,337 (Hunt et al.) 01 May 1990, figure 1 and column 4, lines 23-66.	3-5, 15-16, 21, 26-27, 29-31 and 35

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be part of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 28 FEBRUARY 1994	Date of mailing of the international search report MAR 23 1994
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks	Authorized officer

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US93/12141

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

I. Claims 1-35, drawn to a method and an apparatus for inspecting the surface of an object, classified in Class 382, subclass 8.

II. Claims 36-37, drawn to a method for the production of aluminum alloy sheet stock, classified in class 148, 552.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
-34

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US93/12141

B. FIELDS SEARCHED
Minimum documentation searched
Classification System: U.S.

G06K 9/00, G06K 9/36, G06K 9/48, H04N 7/00, G01B 11/14, G01B 11/24, G01B 11/02, G01B 9/08, G01B 11/00
382/1, 8, 22, 41; 356/375, 376, 383, 384, 392, 394; 358/101, 106, 107